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Next generation ensemble data assimilation to include state dependent observation error

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Next generation data assimilation methods must include the state dependent observation errors, i.e., the spatial and temporal variations produced by the underlying atmospheric turbulent field. The standard optimal interpolation or maximum likelihood assimilation algorithms can be extended to correctly include the spatial variability of both the background error correlations and the total observation error correlations assuming the local turbulent field is a homogeneous Gaussian random process. A rigorous derivation requires a definition of model "truth" or perfect measurement which is required to define the total observation error and thus the observation error statistics. A perfect measurement at each analysis point is defined as a spatial average of the random atmospheric variables centered on the analysis point. The observation errors then consist of two independent components: an instrument error and a sampling error which is essentially the mismatch of the spatial average of the observation and the spatial average of the perfect measurement. The sampling error is related to the "error of representativeness" but defined only in terms of the local statistics of the atmosphere and the sampling pattern of the observation. Optimal data assimilation requires an estimate of the local background error correlation as well as the local observation error correlation. Both of these local correlations can be estimated from ensemble assimilation techniques where each member of the ensemble are produced by generating and assimilating random observations consistent with the estimates of the local sampling errors based on estimates of the local turbulent statistics. The local observation error correlation is calculated assuming a universal statistical description of the random fields and a universal spatial filter of the forecast model. The conditional analysis error, the total analysis error, and the contribution of the turbulent field to the average forecast error are also derived and calculated for the current climatology of upper tropospheric turbulence.